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DESIGN OF THE ADVANCED HIGH KINETIC ENERGY LAUNCH SYSTEM

W. V. Hill
Black & Veatch
Kansas City, Missouri

ABSTRACT

This report describes the design of a facility to provide for destructive testing of U.S. and foreign munitions, up to and including 155 mm. The facility consists of a Range Tunnel designed to resist the muzzle blast of an artillery weapon and a large steel dome structure designed to contain the blast effects of 64 pounds of TNT.

INTRODUCTION

The Advanced High Kinetic Energy Launch System is to provide the Ballistic Research Laboratory (BRL) a facility for the destructive testing of U.S. and foreign munitions, up to and including 155 mm. Munitions to be tested include kinetic energy projectiles (KE), advanced chemical energy (CE), self-forging fragment (SFF), and reactive armors (RA).

The facility consists of a Range Tunnel, 25 feet wide, 21 feet 3 inches high, and 280 feet long (See Figure 1). There is a suppressive door at the entrance to the tunnel to trap missiles and fragments should an accidental explosion occur in the tunnel. The Target Room is a steel dome-shaped structure 60 feet in diameter, designed to contain the blast effects of 64 pounds of TNT. The equipment door is 14 feet wide by 18 feet high. The Instrumentation Building is 16 feet by 33 feet and is constructed of concrete block. The well provides 30 gallons per minute of water for washdown of the Range Tunnel and Target Room. The Holding Tank contains the contaminated washwater and the exhaust filter system removes radioactive dust from the Target Room. Site work includes access roads, parking area, electrical power service, area lighting, underground telephone cable, and a cable trench from the Instrumentation Building to an existing Control and Firing Building. At the present time, the

facility is under construction at Aberdeen Proving Ground, Maryland and is scheduled to be completed early in 1983.

RANGE TUNNEL

The Range Tunnel is designed to resist the dynamic loads from the muzzle blast of an artillery weapon. The muzzle blast loads, at various angles of incident, were provided by Dr. Charles Kingery of BRL. From the blast data received, we developed the idealized pressure-time curves for an angle of incident of 0, 30, and 45 degrees. The idealized pressure-time curves were developed by the use of methods given in Reference No. 1. The maximum load occurs at an angle of incident of 45 degrees where the peak reflected pressure is 57 psi, duration of the positive phase is 4.5 milliseconds, and the positive reflective impulse is 128 psi-milliseconds (see Figures 2 and 3).

The original criteria and concepts called for the Range Tunnel to be constructed of existing armor plate. When the actual design of the Advanced High Kinetic Energy Launch System started, the armor plate had been used in another project. Both steel plate and reinforced concrete were investigated for use in the construction of the Range Tunnel. The reinforced concrete had the lower cost. An economic study on various thicknesses of concrete and the amount of reinforcing required was also made.

For the design of the Range Tunnel, we used a dynamic load factor calculated using Reference 2. The design of the roof slab was then checked by using the Acceleration-Pulse Extrapolation Method of Numerical Integration given in Reference 3.

As you can see from Figure 4, for the roof slab design the values for both the dynamic load factor method and numerical integration are identical, except for the time of maximum deflection. The 6.30 milliseconds was the increment of time nearest to the 6.21 milliseconds. The clear span of the walls are 16 feet and the roof slab spans 20 feet. The elastic unit resistance is 73.0 psi for the walls and 46.7 psi for the roof slab. The natural period of vibration for the walls is 11.9 milliseconds and 18.6 milliseconds for the roof slab. The dynamic load

factor for the walls is 1.03 and for the roof slab 0.71 milliseconds. The equivalent elastic deflection is 0.0503 inches and 0.0785 inches. The maximum deflection is 0.040 inches and 0.068 inches. The maximum deflection occurs at 4.32 milliseconds for the walls and 6.21 milliseconds for the roof slab. Dividing the elastic deflection into the maximum deflection gives a ductility ratio of 0.80 for the walls and 0.87 for the roof slab.

Using a thickness of 2 feet 6 inches, with No. 9's at 12 inches for the positive reinforcing steel and No. 11's at 12 inches for the negative reinforcing bars proved to be the most economical section (see Figure 5). Temperature reinforcing is No. 8 at 14 inches each face. The direct tension bars are No. 10's at 12 inches and No. 4 stirrups were used at 12 or 14 inches, as required. The reinforcement used was ASTM A615, Grade 60 except for the stirrups for which Grade 40 was used. Two 7/8-inch bolts were installed on the centerline of the roof for a future 5-ton monorail to be installed when funds become available.

TARGET ROOM

Figure 6 shows the floor plan of the Target Room. The structure is designed for repeated blast loads of 64 pounds of TNT equivalency. Some of the ammunition to be tested will contain heavy metal and it was necessary to design the Target Room to contain the explosion, except for leakage through the shot hole into the Range Tunnel and through the vents into the filter system. On each side of the doors you can see the structural tee stiffeners. The opening through the mat foundation in the center is for placement of the targets.

The upper part of the Target Room is designed as a dome with a radius of 29 feet 6 inches (see Figure 7). The dome is supported by a ring beam constructed of one-inch plates. The lower portion of the Target Room, below the ring beam, is a section of a cone. The diameter of the top of the cone, where it is attached to the ring beam, is 46 feet 9 inches and the diameter of the base of the cone is 59 feet. The height of the section of the cone, below the ring beam, is 18 feet one inch and the rise of the dome is 11 feet 6 inches.

The Target Room was designed by the trial-and-error method. We first assumed the structural members then we reviewed the structure to determine the stress in the members. The blast loadings on the interior of the Target Room from 64 pounds of TNT were also received from BRL. From these, we developed the idealized pressure-time curve (see Figure 8). The peak gas pressure is 15 psi. Even though there is some decaying of the gas pressure, we assumed a zero rate of decay and considered the 15 psi gas pressure to be constant. The peak positive reflected pressure was calculated to be 75 psi, giving a total peak positive pressure of 90 psi. The positive reflected impulse is 60 psi-milliseconds and the duration of the positive phase is 1.6 milliseconds.

To obtain the natural period of vibration of the various members of the Target Room, we used a computer program called the "Finite Element Method for the Dynamic Analysis of Structures Subject to any Dynamic Loading" (Reference No. 4).

The dynamic load factor was then calculated. For the gas pressure, a dynamic load factor of 1 was used and the gas pressure was considered constant. An equivalent static load was then calculated and STRUDL was used to find the stresses in the various members (Reference 5).

For our first trial, we used vertical stiffeners between the ring beam and foundation on 4-foot 2-inch centers completely around the structure. The analysis showed that the side wall plates were carrying the loads in ring tension and the stiffeners near the door were the only ones being stressed. The next step was to keep eliminating stiffeners. The final design has three stiffeners on each side of the equipment door and one on each side of the personnel door (see Figure 6). Additional steel plates were welded around the other openings. Everything was designed with a ductility factor less than 1 so all elements would remain in the elastic range.

Both the side walls and dome were constructed of one-inch plate. For the dome and ring beam, we used ASTM A516 steel, Grade 70, which has a minimum yield stress of 38,000 psi, and using a dynamic increase factor of 1.1 resulted in a dynamic yield stress of 41,800 psi. ASTM

A516 steel was used for the dome because it is easy to shape and is readily weldable. ASTM A572, Grade 60 is classified as a high strength, low alloy structural steel and was used for its availability, high strength, and weldability for the rest of the structure. The minimum yield stress is 60,000 psi and it has a dynamic yield stress of 66,000 psi.

The maximum circumferential stress in the dome is 7,560 psi and the maximum meridional stress is 9,050 psi (see Figure 9). The maximum stress in the ring beam, which occurs at the equipment door jambs, is 16,800 psi. Using ASTM A516 steel the dynamic yield stress was 41,800 psi. For the side walls the maximum circumferential stress is 14,780 psi and the maximum meridional stress is 7,410 psi. The maximum stress was in the door jambs which were subject to tension and bending in two directions. The stress was 45,700 psi. The stress in the door stiffeners along each side of the equipment door was 49,380 psi and the maximum stress in the equipment door itself was 51,300 psi. For the side walls, door jamb, door stiffeners, and door, the dynamic yield stress of the steel used is 66,000 psi.

Some of the armor piercing ammunition to be tested contains heavy metal which has a low grade of radioactivity. Upon striking the target, the projectile explodes and the dust formed cannot be discharged into the atmosphere. The air evacuation and filtration system consists of a fan which pulls 24,000 cubic feet per minute of air through the suppressive door (see Figure 10).

The door is constructed of interlocking wide flange beams. This allows air to pass through the door but will trap missiles and fragments should an accidental explosion occur in the tunnel. Air is pulled from the tunnel into the Target Room through the 36 inch diameter shot hole. The contaminated air leaves the Target Room through two 36 inch diameter ducts to the attenuators. The attenuators are used to protect the filters from excessive blast pressures. The attenuators were existing and furnished by BRL. They are 10 feet in diameter and 50 feet long, made up of one-inch plate. No attempt was made to determine how effective the

attenuators will be in reducing the blast pressure to the filters. Three sets of filters are used in series: prefilters, secondary filters, and high efficiency particulate air filters which have an efficiency of not less than 99.99 percent when tested with 0.3 micron smoke.

The personnel door and the equipment door are sealed by using compressed air seals. Provisions have been made to wash down the dust that gets into the Range Tunnel through the shot hole. Miscellaneous items in the Range Tunnel and Target Room include view ports for cameras and lighting, tie downs for the weapon, unistruts for attaching equipment to the walls, PA system, telephone, power receptacles, and lighting.

REFERENCES

1. TM 5-1300, Structures to Resist the Effects of Accidental Explosions, June 1969 and Change No. 1, dated March 1971.
2. TM 5-856-3, Principles of Dynamic Analysis and Design, March 1957 and Change No. 2, dated November 1973.
3. C. H. Morris, R. J. Hansen, M. J. Holley, J. M. Biggs, S. Manyet, and J. K. Minami, Structural Design for Dynamic Loads, 1959.
4. Computer Program S73, Dynamic Stress Analysis Axisymmetric Structures, Black & Veatch, February 1976, Revised January 1980.
5. Computer Program S50, Structural Design Language (Univac 1100 ICES/STRUDL), Black & Veatch, September 1975, Revised November 1980.

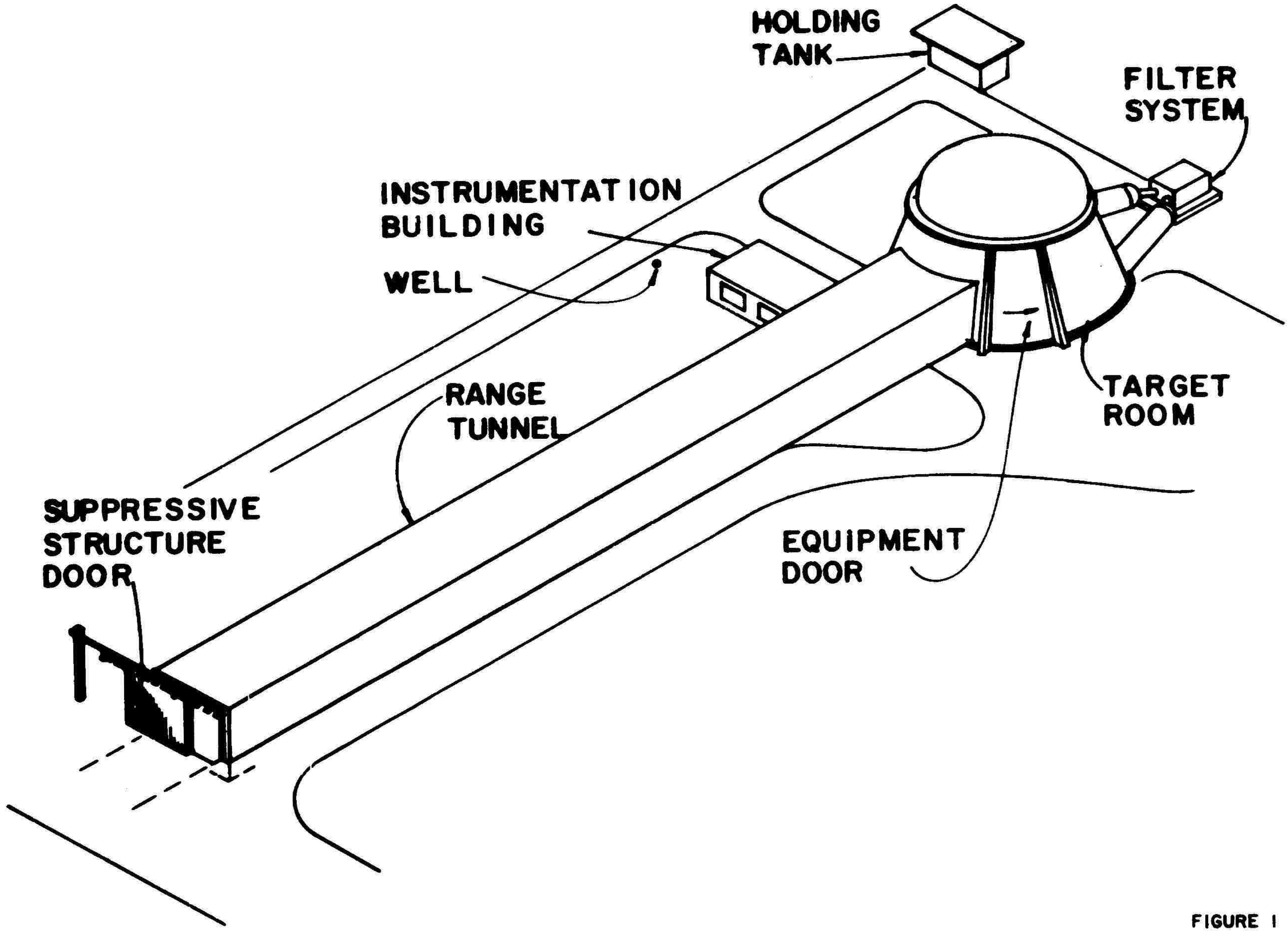
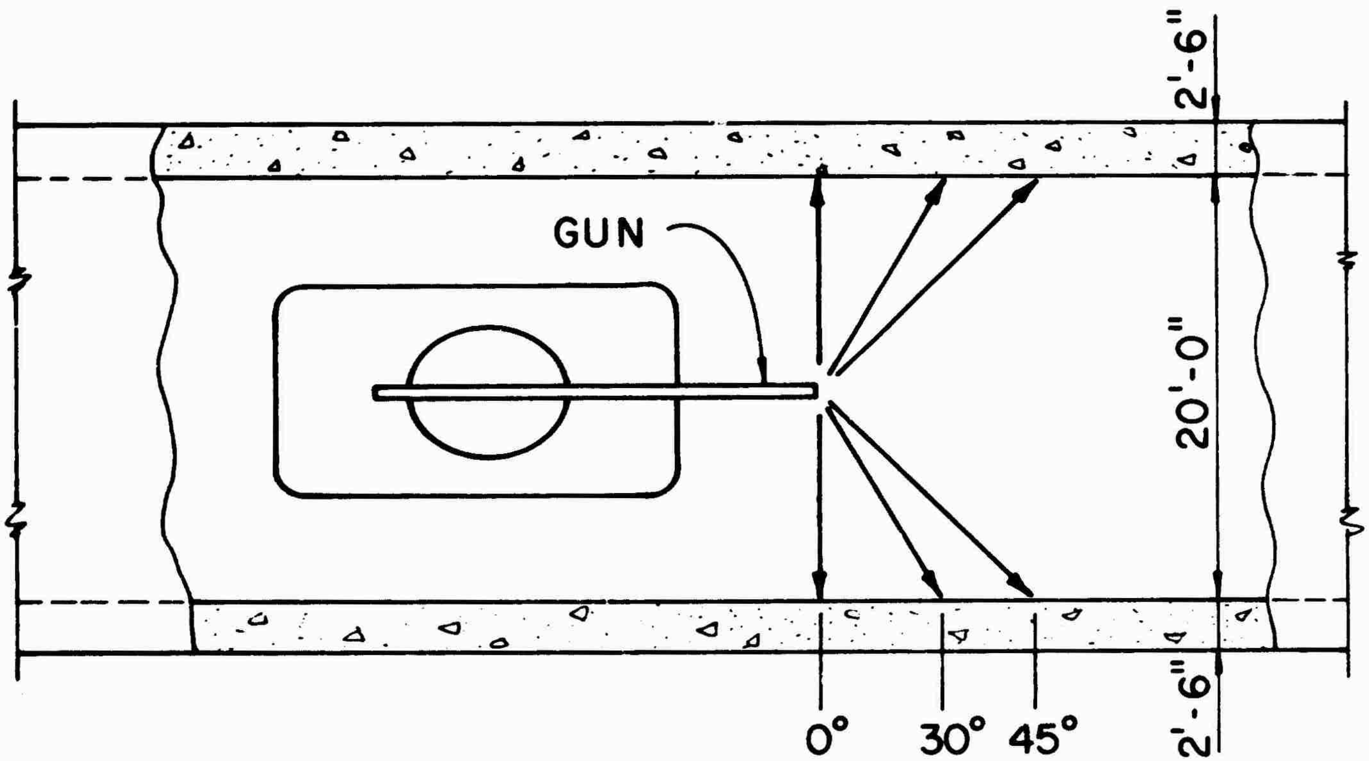
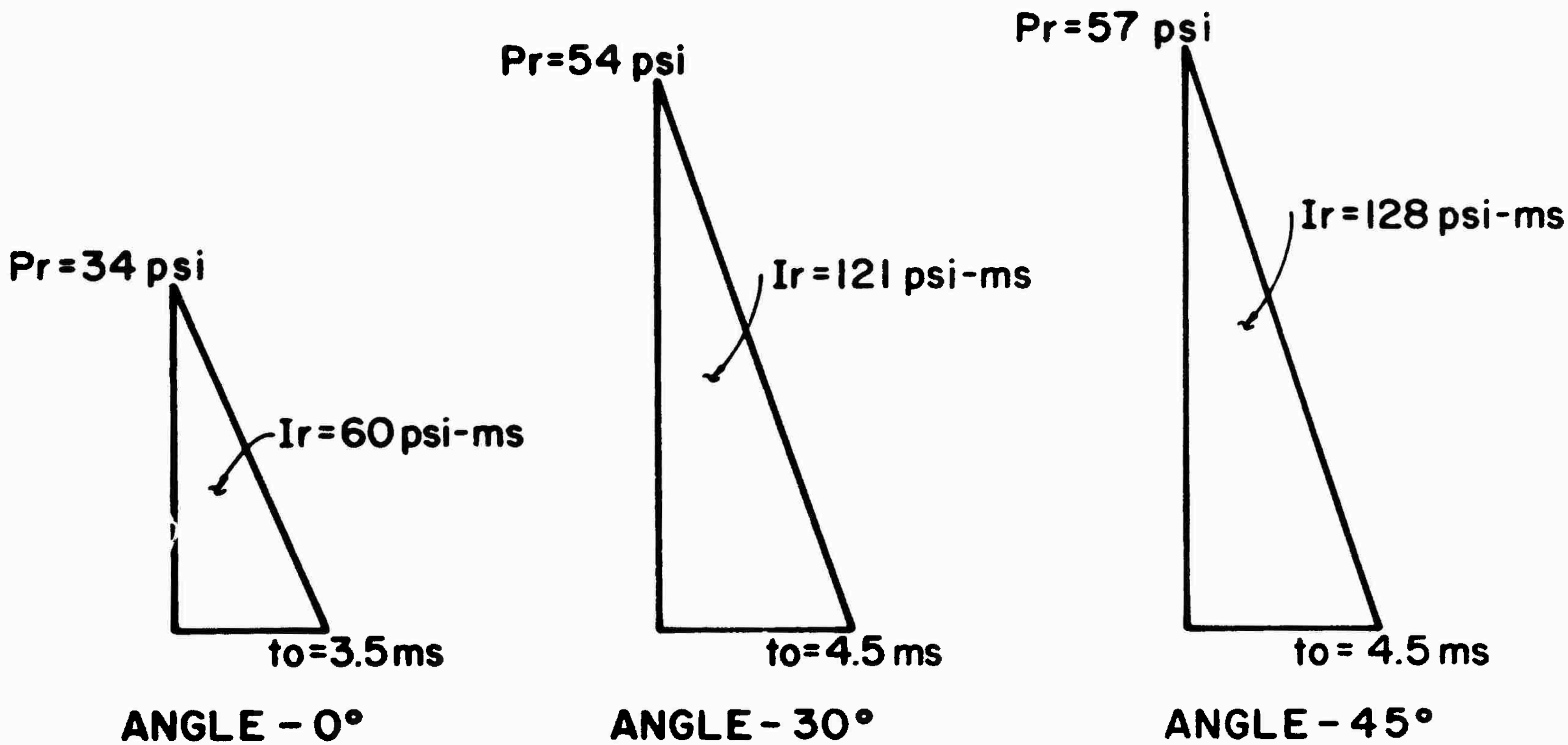

HOLDING
TANK
FILTER
SYSTEM
INSTRUMENTATION
BUILDING
WELL
RANGE
TUNNEL
TARGET
ROOM
SUPPRESSIVE
STRUCTURE
DOOR
EQUIPMENT
DOOR

FIGURE 1



PLAN RANGE TUNNEL

FIGURE 2



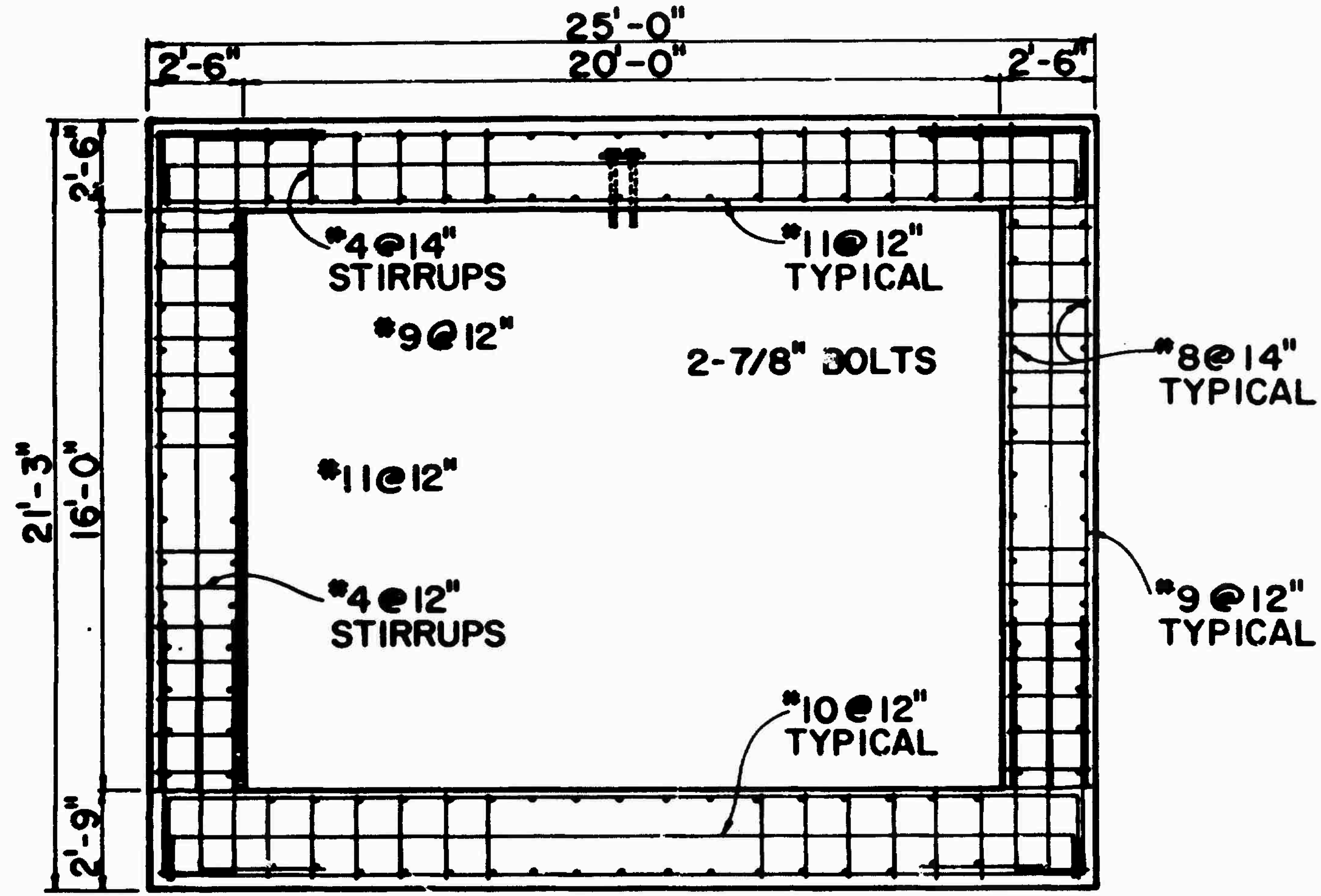
IDEALIZED PRESSURE–TIME CURVE

FIGURE 3

RANGE TUNNEL

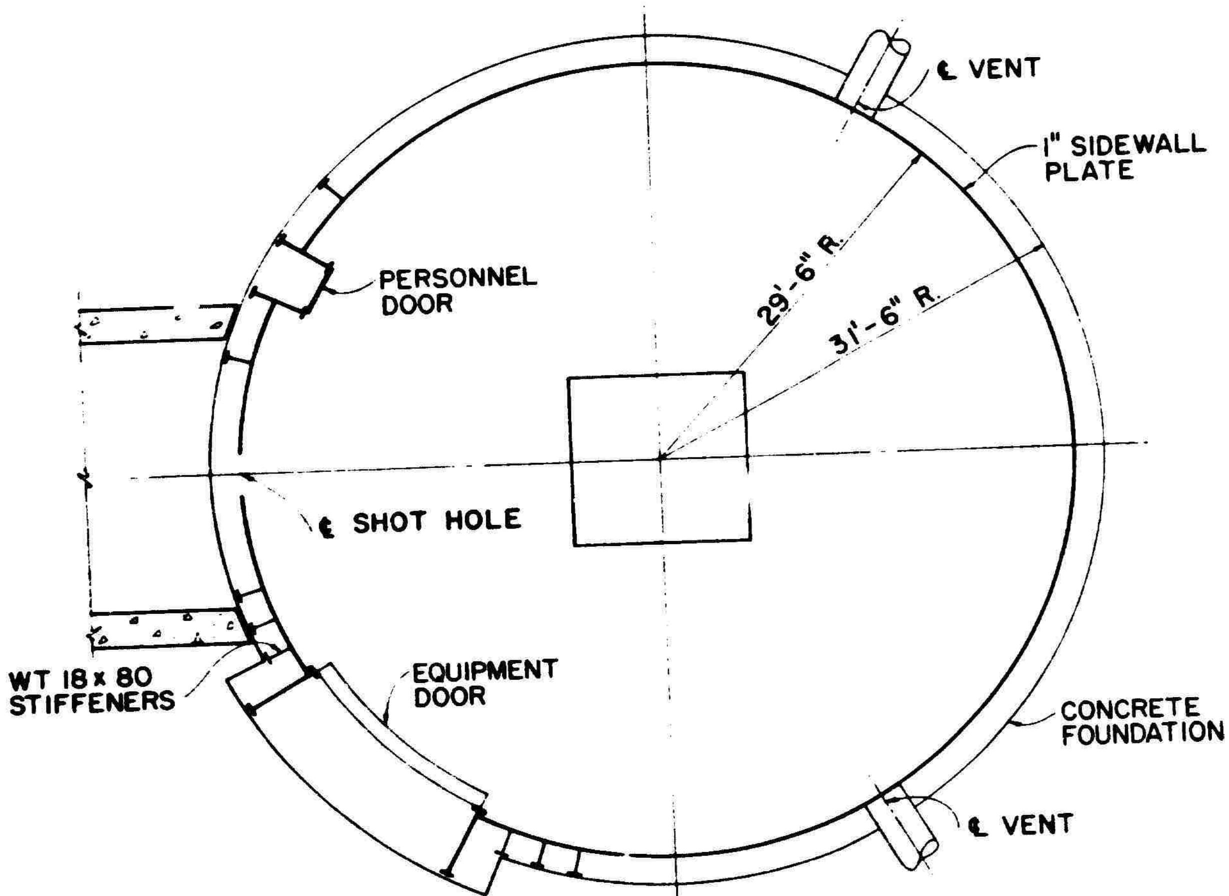
	WALLS	ROOF SLAB	
	DYNAMIC LOAD FACTOR	DYNAMIC LOAD FACTOR	NUMERICAL INTEGRATION
SPAN	16.0'	20.0'	20.0'
ELASTIC UNIT RESISTANCE	73.0 psi	46.7 psi	46.7 psi
NATURAL PERIOD OF VIBRATION	11.9 ms	18.6 ms	18.6 ms
DYNAMIC LOAD FACTOR	1.03	0.71	—
ELASTIC DEFLECTION	0.0503"	0.0785"	0.0785"
MAXIMUM DEFLECTION	0.040"	0.068"	0.068"
TIME MAXIMUM DEFLECTION	4.32 ms	6.21 ms	6.30 ms
DUCTILITY RATIO	0.80	0.87	0.87

FIGURE 4



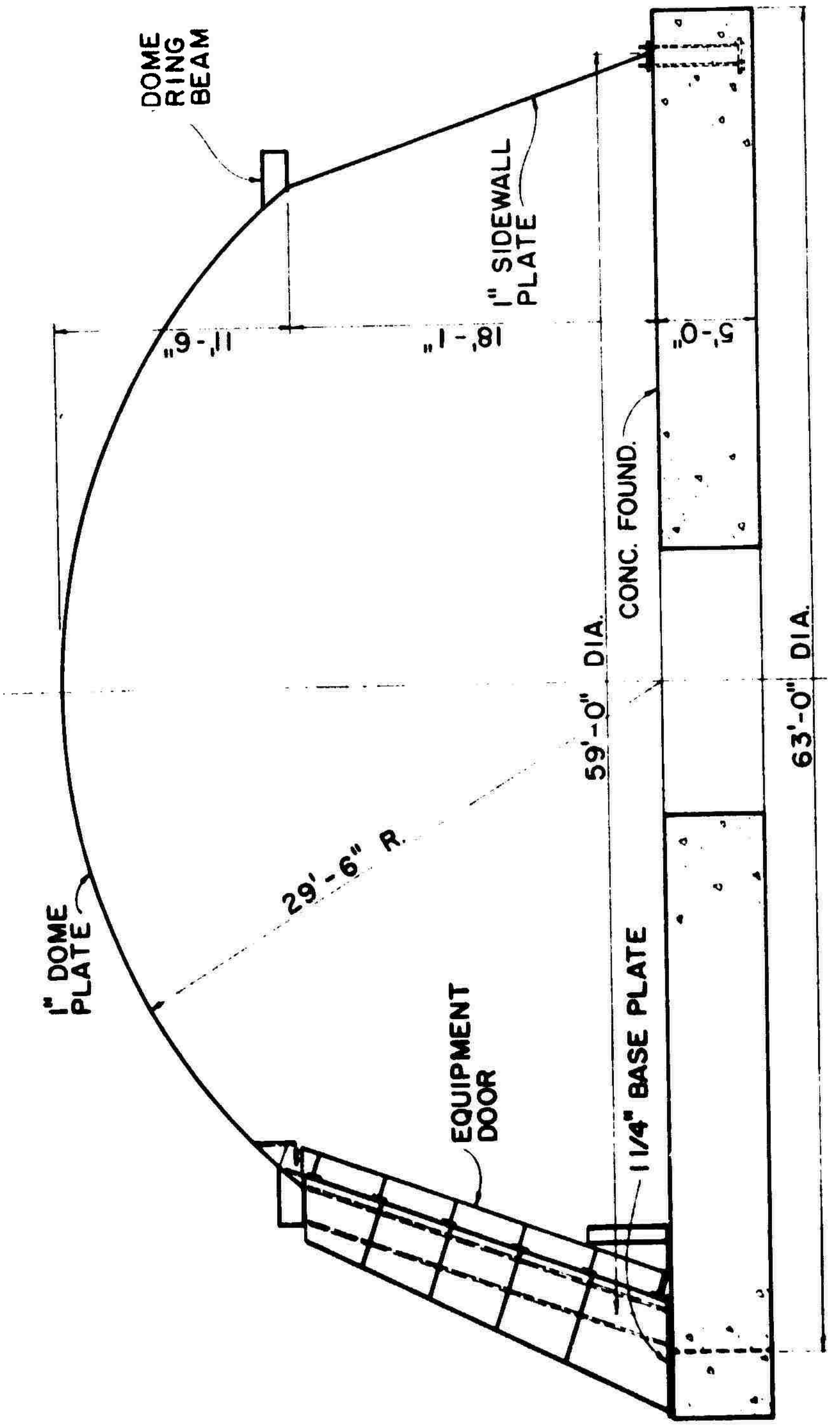
RANGE TUNNEL SECTION

FIGURE 5



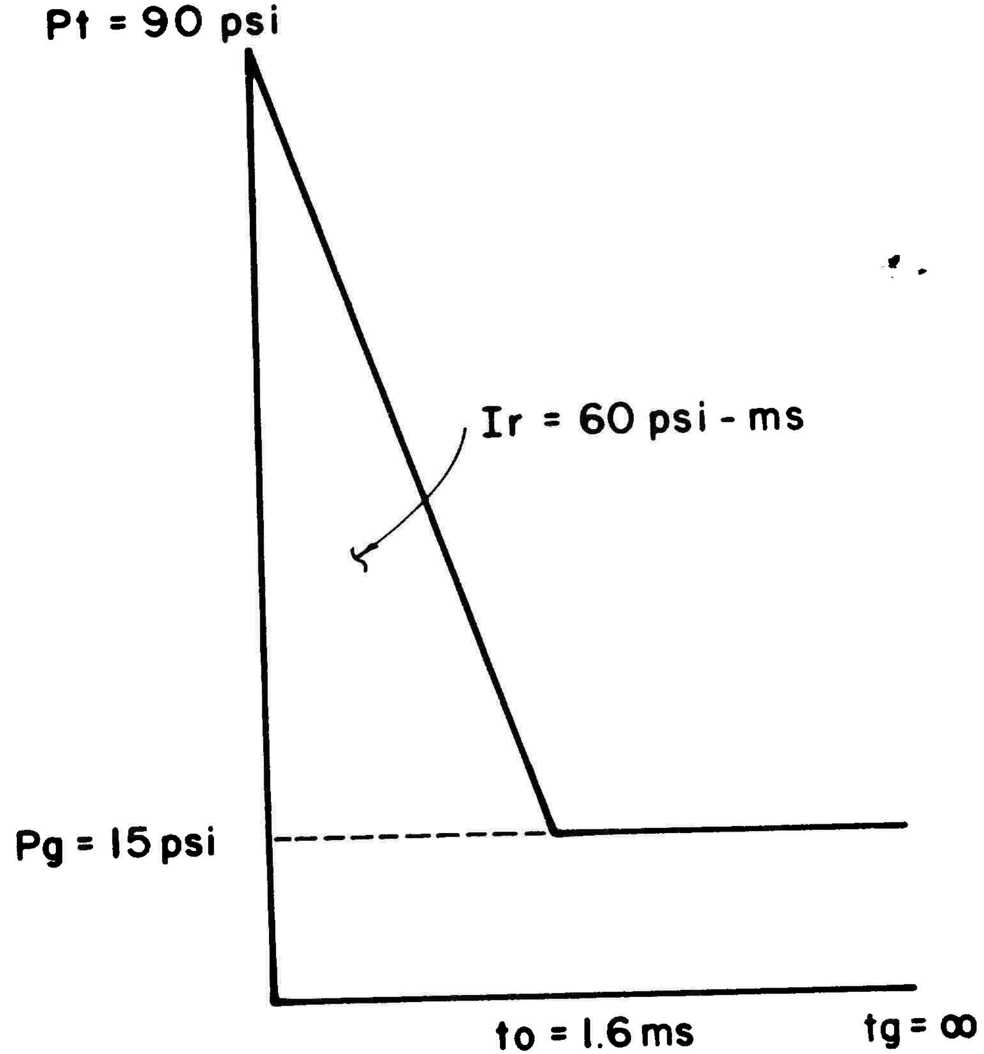
TARGET ROOM PLAN

FIGURE 6



TARGET ROOM SECTION

FIGURE 7



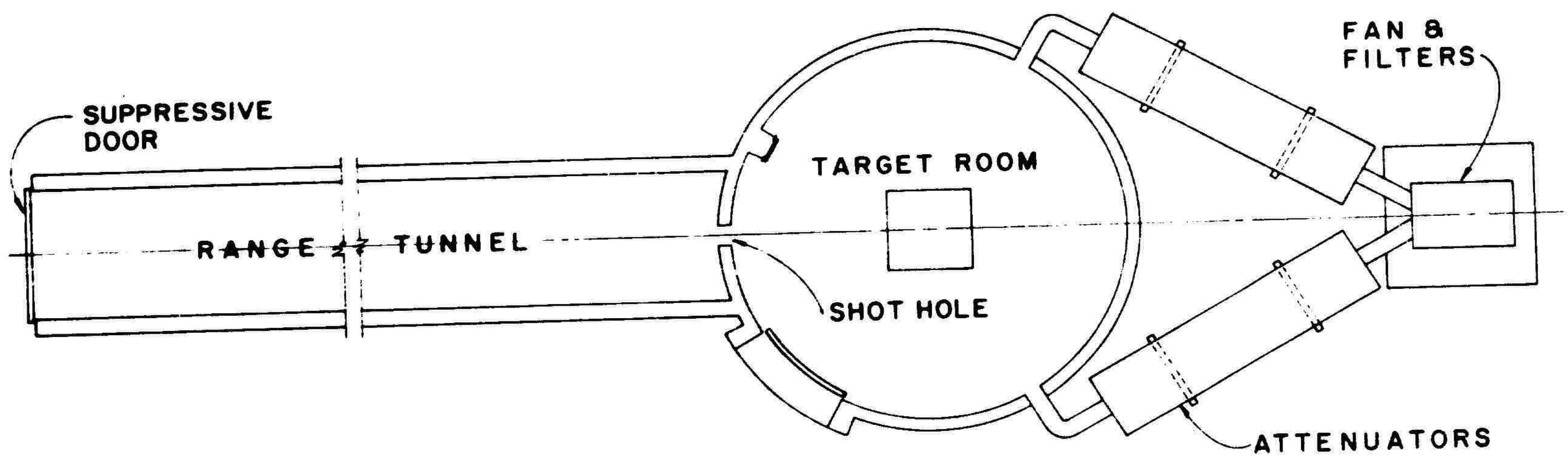
IDEALIZED PRESSURE-TIME CURVE

FIGURE 8

TARGET ROOM

MEMBER	STRESS (psi)
DOME	
CIRCUMFERENTIAL	7,560
MERIDIONAL	9,050
RING BEAM	16,800
SIDE WALLS	
CIRCUMFERENTIAL	14,780
MERIDIONAL	7,410
DOOR JAMB	45,700
DOOR STIFFENER	49,380
DOOR	51,300

FIGURE 9



AIR EVACUATION & FILTRATION SYSTEM

FIGURE 10